Expanding the Use of the Benthic Invertebrate Monitoring Approach Developed for the Fraser River Basin to Assess Streams in the Georgia Basin.

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Abstract

The establishment of the reference condition approach to benthic invertebrate monitoring in the Fraser River Basin in British Columbia has proved to be a useful tool for assessing streams within the basin. In 1998, as part of the Georgia Basin Ecosystem Initiative, this reference condition approach was extended to include the Georgia Basin (lower Fraser River). Disturbed streams in the Georgia Basin are exposed to heavy recreational, urban and agricultural pressures and tend to be slow moving, deep channel, soft bottom streams. In the development of the initial Fraser River database only fast flowing streams with cobble substrates were sampled. We have expanded that database to assess the health of slow moving streams with soft bottoms. Reference streams with these characteristics were added to the database and a new predictive model for agricultural and urban test sites was developed. This new model allows the assessment of many disturbed streams in the Georgia Basin. The assessment of 12 test sites exposed to agricultural and residential activities varied from “not stressed” for a stream running through a small residential development to “very stressed” for a stream running through agricultural land. In 1999 and 2000, 12 additional sites exposed to urban activities in the Greater Vancouver area were also sampled to test for levels of environmental stress using the modified Fraser River Basin model.

Introduction

Worldwide biomonitoring programs are commonly based on the benthic macroinvertebrate community (Rosenberg and Resh 1993). During the Fraser River Action Plan (FRAP), the environmental health of the Fraser River Basin in British Columbia was assessed by developing an invertebrate monitoring program (Rosenberg and others 1999). This program is currently being extended in the Lower Fraser Valley, which is part of the Georgia Basin (an area encompassing the Strait of Georgia from its southern extremity north to about Campbell River and the watersheds from Vancouver Island and the mainland [downstream of Hope] draining into the strait).

The monitoring approach was modified from approaches used in the United Kingdom (Wright and others 1984) and in Australia (Parson and Norris 1996). The common theme in these programs is the use of a *reference condition approach* (Reynoldson and others 1997). This approach requires that an extensive database of regional reference sites be developed to incorporate a range of invertebrate reference communities from a large range of reference habitats. The *reference condition* is defined as the “condition that is representative of a group of minimally disturbed sites organized by selected physical, chemical and biological characteristics” (Reynoldson and others 1997). The concept of the monitoring approach is that reference sites with similar invertebrate communities are grouped together and the physical and chemical variables that discriminate the groups are then used in a predictive model. In applying the model, potentially impaired or test sites are matched to the most appropriate group of reference communities based on the environmental variables. The assessment of the test sites is made by the comparison of the invertebrate community found at the test site with the invertebrate communities of the group of reference sites it was matched to. Significant digression of the test community from the reference communities indicates impairment.

During FRAP, this approach was successfully used to assess streams from the headwaters of the Fraser River watershed to as far down the watershed as Chilliwack (Rosenberg and others 1999). Most of the lower Fraser Valley, from the river's mouth to approximately 120 km east of Vancouver, BC, was not included in the design because the stream environments were different than those observed throughout the majority of the basin. This area is of concern due to the disturbances from agriculture and urban pressures on streams in and around the valley. As part of Georgia Basin Ecosystem Initiative (GBEI), a partnership between different levels of government in the province and other stakeholders, the FRAP benthic invertebrate monitoring approach was expanded to assess sites in the lower Fraser Valley.

To properly assess Fraser Valley sites, an appropriate reference needed to be established. The question of what these communities should look like needed to be addressed. This is the question of all bioassessments. Should the communities look like they did historically? Is the best attainable community one which may be observed in a restored stream of similar disturbances? Is the appropriate comparison one with similar habitat variables: slow flow, deep channel, small substrates?

The decision was made to compare the communities in the Fraser Valley streams with reference streams with similar habitats. This approach was taken because historical conditions are likely unattainable as a result of the intense urban and agricultural development. Secondly, baseline conditions prior to development are not known because they have not been documented. And finally, few restoration projects have occurred on streams in and around the valley.

The objective of this paper is to describe how the reference condition approach was expanded to increase the range of variability of the FRAP database in the development of a new GBEI model and to report on the assessment of sites exposed to agricultural and urban activities in the lower Fraser Valley.

Methods

Addition of new reference sites to FRAP database

The sites in the lower Fraser Valley were at a lower elevation, with slower flows, deeper channels, and smaller substrates than sites sampled during FRAP. The selection of additional reference sites incorporated these characteristics. Helicopter reconnaissance was used to examine areas of minimal disturbance and select appropriate sites.

In 1998 and 1999, 35 new reference sites were sampled (Figure 1). Within the geographical boundaries of the Fraser River basin, streams near Pitt Lake, Harrison Lake and Stave Lake, as well as streams flowing into the Fraser River just downstream of Hope were sampled. Minimally disturbed upstream areas of creeks flowing into the population centers of Chilliwack and Abbotsford were also selected. Outside of the Fraser River basin, four sites that incorporated the desired habitat variables in the Skagit River Basin near Manning Provincial Park, approximately 25 km west of Hope, were also selected.

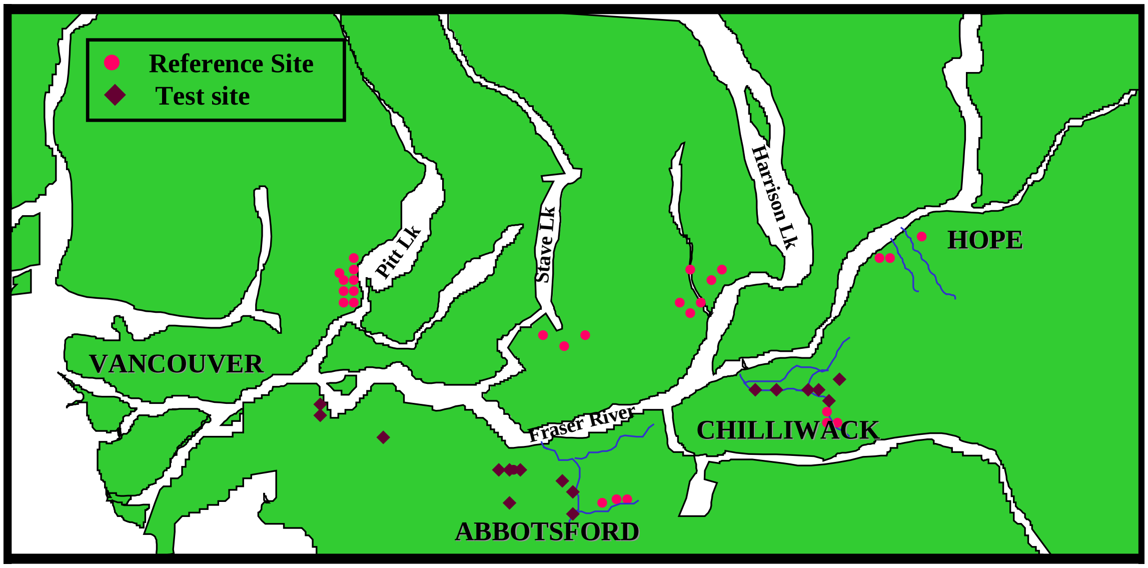


Figure 1. Schematic map of benthic invertebrate sampling sites in the lower Fraser Valley in 1998 and 1999.

Sampling methods

The sampling methods used were consistent with those used in the FRAP program (Rosenberg and others 1999). All sampling was conducted in autumn because it represents a period of low flow and allows accessibility to the streams. The seasonal variability of the FRAP program was addressed by Reece and Richardson (1998). The invertebrate community was sampled with a 400 μm mesh triangular kick net (38.5cm to the side) for a timed kick of three minutes to incorporate all microhabitats at each site. Only one sample was taken at each site. The sample was preserved in 70% formalin. Invertebrate samples were subsampled to 200 organisms. All organisms were identified to species level where possible. Twenty-nine habitat variables used to develop the predictive model were also measured at each site (Table 1). The habitat variables range in spatial scales from geographical descriptors to water-column chemistry. The rationale behind the sampling procedures and the choice of habitat variables are described in Rosenberg and others (1999). All data were maintained in the Benthic Information System for Reference Conditions (BRIC, Pascoe and Reynoldson 1998).

Classification of reference groups

The monitoring approach developed during FRAP uses quantitative abundance counts to describe the invertebrate communities. The FRAP program also recommended the use of family-level data (Rosenberg and others 1999; Reynoldson and others 2001). Classification methods were used to describe the biological structure of the invertebrate communities at the family-level in the FRAP database and the expanded GBEI database. The Bray-Curtis association matrix was used in the cluster analysis using agglomerative hierarchical fusion method with Unweighted Pair Group Mean Averages (UPGMA). Ordination was also used to explain the variability in the large number of taxa with reduced number of new variables (ordination axes). Ordinations and clustering were performed with PATN, a pattern analysis software package developed by CSIRO in Australia (Belbin 1993). The classification of sites into reference faunal groups of the FRAP database and the new GBEI database were compared.

Table 1. Habitat variables measured for the development of a predictive model (modified from Rosenberg *and others* 1999).

Scale	Variable	units
Landscape	stream order	7 categories (1-7)
	latitude	decimal degrees
	longitude	decimal degrees
	altitude	feet above sea level
	ecoregion	11 categories[1]
Site	flow state	3 categories (riffle, run, pool)
	% macrophyte cover	5 categories (0, 25, 50, 75, 100)
	presence of grasses	2 categories (0, 1)
	presence of shrubs	2 categories (0, 2)
	presence of deciduous tress	2 categories (0, 3)
	presence of coniferous trees	2 categories (0, 4)
	riparian vegetation	10 categories (sum of above 4 variables)
Channel	wetted width	m
	bankfull width	m
	average depth	cm
	maximum depth	cm
	slope	m/m
	average velocity	m/s
	maximum velocity	m/s
	substrate framework	7 categories[2]
	substrate matrix	7 categories[3]
	substrate embeddedness	5 categories[4]
	gravel	% of interstitial material
	sand	% of interstitial material
	silt	% of interstitial material
	clay	% of interstitial material
Water-column	pH	relative units
	alkalinity	mg/L
	conductivity	µS/cm

[1]B.C. Ministry of Environment, Lands and Parks 1991.
[2]Dominant substrate size in sampling area: 1, <0.02cm; 2, 0.2-0.5cm; 3, 0.5-2.5cm; 4, 2.5-5 cm; 5, 5-10 cm; 6, 10-25 cm; 7, >25 cm.
[3]Substrate size surrounding dominant substrate: 1, <0.02cm; 2, 0.2-0.5cm; 3, 0.5-2.5cm; 4, 2.5-5 cm; 5, 5-10 cm; 6, 10-25 cm; 7, >25 cm.
[4]Estimated in sampling area: 1, completely embedded; 2, 75% embedded; 3, 50% embedded; 4, 25% embedded; 5, unembedded.

Development of predictive model

Principal axis correlation (PCC in PATN) was used to determine which habitat variables were significantly correlated with the invertebrate data in ordination plot. Stepwise discriminant function analysis was performed in SYSTAT 7.0.1 (SPSS 1997) to establish which habitat variables best separate sites into the predefined reference faunal groups formed by the classification of the invertebrate data. The resultant variables were used to develop the predictive model. Final selection of the optimum variables from the habitat data was done by iteration of the stepwise model with significant variables determined by the PCC analysis. Combinations of various predictor variables were tried and the performance of the models to accurately predict the reference communities to the predefined faunal groups was assessed (Rosenberg and others 1999). The accuracy of the models was evaluated in SYSTAT 7.0.1 by resubstitution and cross-validation in the Discriminant Analysis procedure. Resubstitution uses a reference site to both estimate the model and evaluate the success of the model, whereas cross-validation evaluates the model, one site at a time, with a site that is not used to derive the model. Various models were examined by iteration by adding and replacing variables.

Assessment of test sites

In the lower Fraser Valley, 16 test sites (potentially impaired sites) exposed to agricultural and urban activities were sampled. Both invertebrate and habitat data were collected. After the development of the new GBEI model, habitat data from the test sites were used to predict the test site community to a reference faunal group with which it should be most similar. The model provided a probability of group membership for each of the predefined faunal groups. The group with the highest probability was the group to which the test site was predicted and assessed with. Due to the degree of overlap between neighbouring groups, some test sites had equal probabilities of belonging to more than one group and were therefore tested with each of those groups.

To assess the test site, the actual community at the test site was compared with the communities of the reference faunal group to which it was predicted. This comparison was done by plotting the biological data of the test site and the reference faunal group in ordination space. The departure of the test site from reference condition was assessed by the distance the test community fell away from the cloud of reference sites of the predicted faunal group. The reference group to which the test site was predicted is assumed to contain the expected range of variation in invertebrate communities at the test site if it was unimpaired and the variance in communities is defined by probability ellipses drawn around the cloud of reference sites (Figure 2). Sites that fell within the 90% probability ellipse in Band 1 were considered not stressed since they are similar to the reference communities. Test sites that fell just outside of the 90% probability ellipse in Band 2 were considered possibly stressed since 10% of the reference sites will also fall outside of this ellipse. Sites that fell just outside of the 99% probability ellipse in Band 3 were considered stressed. Test sites that fell outside of the 99.9% probability ellipse in Band 4 were considered severely stressed because the invertebrate communities were very different than the group of reference communities they were predicted to belonging.

Results and Discussion

Addition of new sites to the FRAP database and classification of reference groups

The original FRAP database contained 219 reference sites sampled between 1994 and 1996 (Rosenberg and others 1999). An additional 35 reference sites, determined *a priori*, were added to the database. These sites were selected based on the presence of one or more of the following characteristics; slow flow, deep channel, small substrate and low elevation and were in the lower Fraser Valley or just outside of the Fraser River basin in southern BC. The additional sites had 13 new taxa at the family level, primarily from the water mite and beetle orders, that were not present in the FRAP database. A cluster analysis was performed on this new expanded GBEI database with the expanded taxa list and the new classification was compared with the original FRAP clusters.

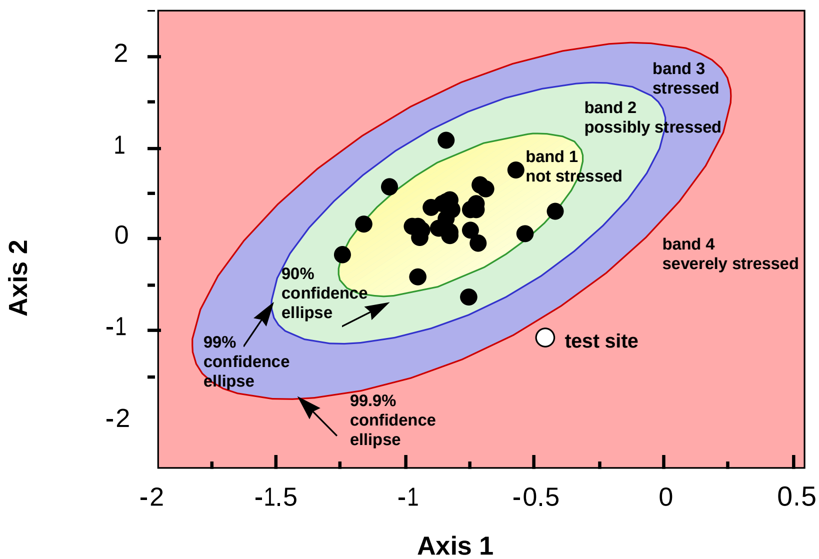


Figure 2. Ordination plot based on invertebrates assemblages of a test site with the predicted group of reference sites. Probability ellipses surrounding the reference communities (black circles) define bands describing various degrees of stress that may be observed by the test site community (white circle).

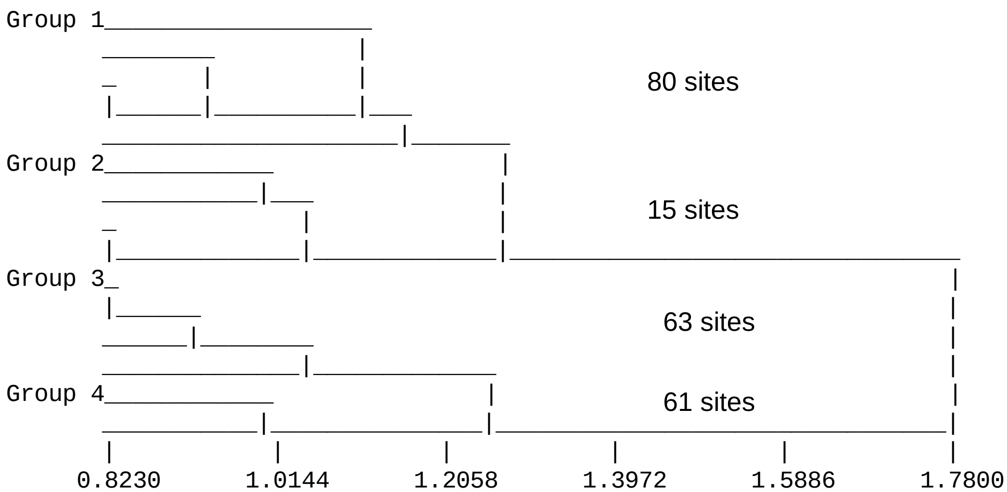
Cluster analysis of the FRAP family-level invertebrate data revealed 4 faunal groups consisting of 80, 15, 63 and 61 sites. With the addition of the new GBEI sites, the cluster analysis also revealed 4 faunal groups of 83, 16, 86 and 69 sites. The new GBEI sites were distributed among the four faunal groups rather than forming their own distinct group (Figure 3) indicating that the range of communities in the FRAP database included the range of communities found in the new reference sites. The sites within each faunal group were similar between FRAP groups and GBEI groups with the exception of some crossover between neighbouring groups.

The faunal groups were similar in the common taxa (Table 2). Chironimidae were present at nearly 100% of the sites in all faunal groups. The mayflies Heptageniidae, Baetidae and Ephemerellidae were next the most common families in groups 1, 3 and 4. Group 2 was most distinct having worms, water mites and Ameletidae mayflies among the most common taxa in the group. The common taxa in Group 1 were primarily stoneflies. The Diptera families, Tipulidae and Empididae, were common taxa in Group 3 while the Leptophlebiidae mayfly and the Elmidae beetle were common taxa in Group 4.

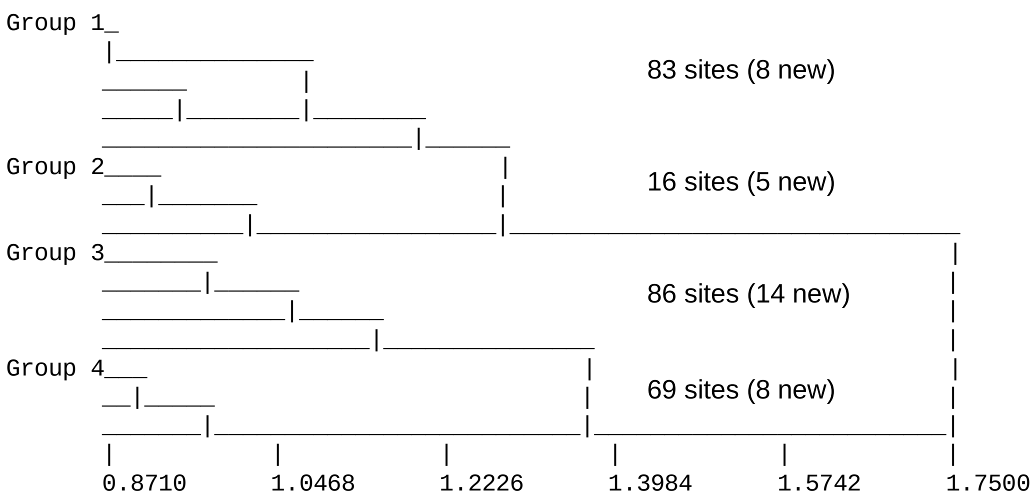
Table 2. Top ten most common taxa in 4 faunal groups of the GBEI database as expressed by per cent of sites with taxa present in each group.

Group 1	%	Group 2	%	Group 3	%	Group 4	%
Heptageniidae	99	Chironomidae	100	Chironomidae	100	Chironomidae	100
Chironomidae	98	Naididae	55	Heptageniidae	99	Baetidae	91
Baetidae	94	Limnesiidae	55	Baetidae	90	Heptageniidae	88
Ephemerellidae	92	Baetidae	55	Ephemerellidae	89	Ephemerellidae	84
Chloroperlidae	89	Ameletidae	55	Chloroperlidae	81	Nemouridae	77
Perlodidae	81	Tubificidae	50	Nemouridae	75	Chloroperlidae	68
Nemouridae	77	Capniidae	50	Capniidae	70	Capniidae	67
Taeniopterygidae	75	Chloroperlidae	45	Tipulidae	65	Leptophlebiida e	62
Rhyacophilidae	66	Ephemerellidae	45	Perlodidae	61	Elmidae	57
Capniidae	64	Lumbriculidae	45	Empididae	60	Perlodidae	57

The most common taxa in groups 1, 3 and 4 were also the most abundant (Table 3). The groups are differentiated by the relative abundances of those common taxa. Thirty-five per cent of the organisms in group 4 were chironomids followed by baetids at 16% while in group 3 the proportions of those taxa were approximately equal and in Group 1, baetida were nearly twice as abundant as chironomids. Group 1 was distinct from the other groups by the predominance of the Taeniopterygidae stonefly. Heptageniidae was approximately twice as abundant than Ephemerellidae in Group 1 and Group 4 while they were nearly equally proportioned in Group 3.



A. FRAP



B. GBEI

Figure 3. Simplified dendograms of cluster analysis of invertebrate assemblages identifying 4 faunal groups from (A) the FRAP database of 219 sites and 74 families, and (B) the GBEI database with 254 sites and 87 families. The number of new GBEI reference sites in each cluster are indicated in brackets.

Table 3. Top five most abundant taxa in 4 faunal groups of the GBEI database as expressed by per cent of total organisms in each group.

Group 1	%	Group 2	%	Group 3	%	Group 4	%
Taeniopterygidae	21	Naididae	35	Baetidae	18	Chironomidae	35
Heptageniidae	18	Chironomidae	28	Chironomidae	17	Baetidae	16
Baetidae	17	Ceratopogonidae	6	Heptageniidae	14	Heptageniidae	14
Chironomidae	9	Tubificidae	4	Ephemrellidae	11	Ephmerellidae	6
Ephemerellidae	7	Ephemerellidae	3	Lepidostomatidae	6	Nemouridae	4

Predictor variables

Table 4 illustrates selected averaged habitat variables of the faunal groups. Group 1 tends to be streams with large substrates, faster velocities and few of the sites had grasses present in the riparian zone. Group 2 sites tend to be from large rivers with deeper channels and smaller substrates but also include some headwater sites from the upper Fraser River. Group 3 and 4 are generally found at higher elevations but primarily differ in depth, substrate size and riparian vegetation.

Table 4. Selected habitat variables (mean +/- SD) of sites in each faunal group from the GBEI database.

Variable	Group 1	Group 2	Group 3	Group 4
Altitude (f asl)	2283 (1520)	2205 (1789)	3141 (1703)	3265 (1559)
Stream Order	2.8 (1.0)	3.4 (1.8)	2.6 (1.3)	2.8 (1.6)
Gravel (%)	23.2 (19.7)	19.8 (19.3)	30.3 (19.0)	30.9 (26.2)
Sand (%)	74.4 (19.2)	76.6 (18.8)	64.7 (23.3)	60.9 (28.1)
Framework	6.6 (1.3)	4.9 (1.9)	6.0 (1.7)	5.0 (1.9)
Alkalinity (mg/L)	32.3 (29.3)	36.2 (31.6)	41.5 (32.6)	57.1 (38.5)
Conductivity (uS/cm)	80.9 (71.4)	89.7 (64.5)	82.8 (64.8)	113.0 (78.9)
pH	7.5 (0.7)	7.2 (1.2)	7.5 (0.8)	7.6 (0.7)
Grass (% sites)	17	31	49	70
Channel width (m)	22.4 (24.8)	63.1 (69.0)	15.2 (25.0)	15.0 (29.2)
Avg depth (cm)	32.5 (13.1)	33.3 (23.0)	26.5 (18.0)	21.1 (11.8)
Avg velocity (m/s)	0.52 (0.21)	0.27 (0.18)	0.37 (0.18)	0.35 (0.19)
Slope	0.018 (0.025)	0.008 (0.015)	0.024 (0.050)	0.009 (0.015)

Principal Axis Correlation (PCC procedure in PATN) was used to determine which environmental variables were correlated with the biological data in ordination space. The results would be used to develop a predictive model by discriminant function analysis (DFA) in conjunction with results of stepwise discriminant function analysis. Of the 29 variables used in the PCC procedure (Table 1), 25 of the variables were significant. Ecoregion, longitude, substrate embeddedness and the presence of shrubs were not significantly correlated with the ordination axes of the invertebrate data.

Stepwise discriminant function analysis selected 6 variables (altitude, substrate framework, channel width, presence of grasses, average velocity, and alkalinity) which correctly predicted 54% of the reference sites to their designated classifications by resubstitution and 52% of the sites by cross-validation. The model with 8 variables included variables from the stepwise model as well as average depth and slope. This model predicted 59% of the sites correctly by resubstitution, and 56% of the sites by cross-validation (Table 5). By adding a ninth variable, the occurrence of coniferous trees in the riparian zone, the accuracy increased slightly to 61%, as determined by resubstitution but decreased it slightly to 55% by cross-validation (Table 5). Cross-validation is the most desirable test of the model accuracy because the model will be used to assign new sites to faunal groups (Rosenberg and others 1999); therefore, the model with the best cross-validation result was used to assess test sites.

Table 5. Performance, determined by resubstitution and cross-validation methods, of various discriminant models for predicting references sites to their designated faunal groups.

Predictive Models	Resubstitution % sites correctly predicted	Cross-validation % sites correctly predicted
GBEI database (254 sites, 87 families)		
*8 variables: altitude, framework, grass occurrence, alkalinity, avg. velocity, avg. depth, width, slope	59	56
9 variables: altitude, framework, grass occurrence, alkalinity, avg. velocity, avg. depth, width, slope, coniferous occurrence	61	55
all 29 variables	65	50
FRAP database (219 sites, 74 families)		
8 variables: ecoregion, latitude, grass, width, max. depth, alkalinity, conductivity, framework	59	56
*9 variables: ecoregion, latitude, grass, width, max. depth, alkalinity, conductivity, framework, longitude	62	56
all 29 variables	67	53

*Indicates the model used for site assessments.

The new GBEI predictive model is similar to the FRAP model for 4 of the variables and in the accuracy of predicting sites (Table 5). While ecoregion, latitude, conductivity and longitude are significant in the FRAP model, altitude, average velocity, average depth, slope and the presence of coniferous tress are important in the new GBEI model. The accuracy of the models from the two databases is similar with the same number of variables. With all 29 variables in the model, the GBEI database is slightly less accurate predicting 65% and 50% of the sites correctly using the two validation methods while the FRAP database predicted 67% and 53% of the site correctly using the two validation methods (Table 5). As with the FRAP model, the GBEI model had the most difficulty distinguishing between groups 1, 3 and 4 suggesting biological similarity between groups. This is most evident by the overlap in ordination space suggesting a continuum of assemblages rather than discrete clusters (Figure 4).

Assessment of test sites

Most of the test sites were predicted to faunal group 4 with more than 50% probability of group membership (Table 6). Only three of the 16 test sites were predicted to faunal group 3 with a probability of group membership of approximately 50% or less. These low probabilities reflect the high degree of overlap in the reference groups in ordination space (Figure 4). In the case where the probability of group membership of a test site is less than 50%, it was assessed with both the predicted group as well as the group with the next highest probability and the most conservative assessment is used. Three sites (ELK04, SMS01, and YOR02) had similar probabilities of belonging to groups 3 and 4 and were therefore assessed with both groups. Assessments of ELK04 and SMS01indicated stress and possible stress while both assessments for YOR02 indicated severe stress (Table 6).

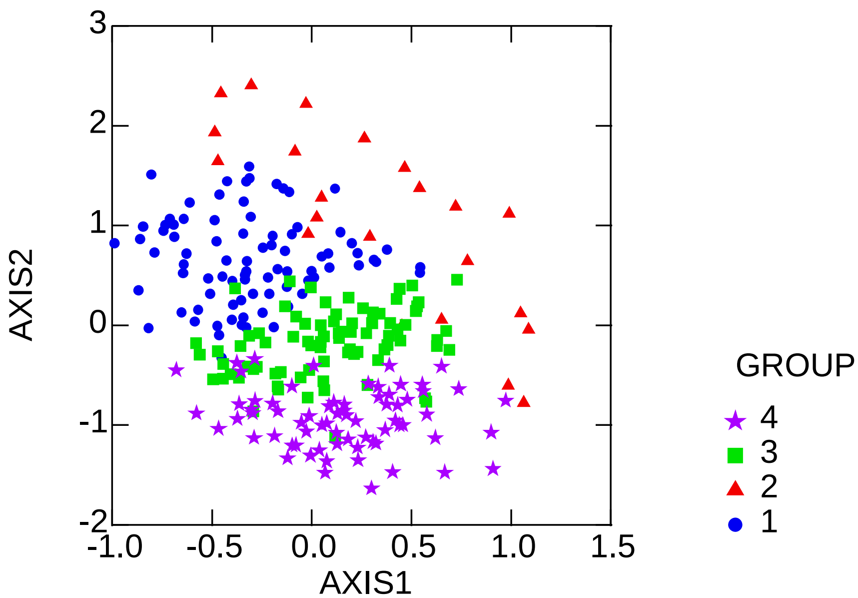


Figure 4. Ordination plot of invertebrate assemblages of the four faunal groups based on Bray-Curtis association matrix.

Table 6. Summary of test site assessments using the GBEI model (altitude, framework, grass occurrence, alkalinity, avg. velocity, avg. depth, width, slope).

	Test Site	predicted group	probability of group membership	assessment	impact
1	CLB04	4	74.9%	possibly stressed	residential
2	CLB05	4	64.0%	possibly stressed	agriculture (corn)
3	CLB06	4	68.3%	severely stressed	industrial
4	ELK04	3	44.4%	possibly stressed	urban
		4	40.4%	stressed	
5	ELK05	4	71.3%	possibly stressed	residential/agriculture
6	ELK06	4	78.6%	severely stressed	agriculture (corn, grass, livestock grazing)
7	ELK07	4	61.5%	possibly stressed	agriculture (corn)
8	ELK08	4	65.8%	possibly stressed	agriculture (grass/corn)
9	ELK09	4	81.9%	not stressed	agriculture (grass)
10	MCL01	4	72.5%	not stressed	agriculture (grass)
11	MCL02	4	72.4%	not stressed	agriculture (livestock grazing)
12	MCL03	4	47.2%	possibly stressed	agriculture (livestock grazing)
13	SLM01	4	67.4%	not stressed	small park/agriculture (livestock grazing)
14	SMS01	3	39.6%	stressed	agriculture (cattle grazing)
		4	42.1%	possibly stressed	
15	YOR01	4	69.7%	severely stressed	urban
16	YOR02	3	45.5%	severely stressed	urban
		4	31.4%	severely stressed	

Eleven of the 16 test sites were sampled from areas of various agricultural influences (i.e., livestock grazing, crop farming; Table 6). Most of the sites indicated little to no stress. Only one site downstream of crop farming and livestock grazing indicated severe stress. One site flowing through a small residential development and another site exposed to both residential and agricultural activities indicated possible stress on the invertebrate communities. Three of the four urban test sites indicated severe stress on the invertebrate communities while the fourth indicated possible stress. The assessment of the severely stressed sites was primarily driven by the relatively large proportion of oligocheate worms, amphipods, isopods, dipterans and sponges in the test sites (Table 7) compared with the group 4 reference sites (Table 2).

Table 7. Dominant taxa in severely stressed test sites as expressed as a per cent of the total abundance.

YOR01		YOR02		CLB06		ELK06	
Crangonyctidae	54.11%	Tubificidae	40.91%	Spongillidae	31.14%	Tubificidae	43.39%
Chironomidae	17.87%	Sphaeriidae	18.83%	Tubificidae	19.16%	Chironomidae	15.34%
Asellidae	7.73%	Stratiomyidae	16.23%	Asellidae	19.16%	Asellidae	7.94%
Lumbriculidae	5.31%	Chironomidae	14.29%	Sphaeriidae	14.37%	Lumbriculidae	6.35%
Naididae	3.38%	Asellidae	2.60%	Chironomidae	11.08%	Lebertiidae	5.82%
Tipulidae	2.90%	Lumbriculidae	2.60%	Physidae	1.20%	Baetidae	4.23%

Conclusions and Future directions

The invertebrate assemblages of the new GBEI reference sites were distributed among four faunal groups which were very similar to the groups formed with the FRAP database. This suggests that the range of variability of the FRAP communities included those observed in the GBEI sites despite the efforts to increase the range of variability of the habitat variables. The FRAP database was easily expanded to include the new GBEI data. The new GBEI model created was similar both in predictor variables and accuracy to the model created in FRAP. Ideally, the database and the model will continue to be built and developed for streams on Vancouver Island and throughout the province of British Columbia.

The results of the lower Fraser Valley test sites suggested that urban activities may be posing more stress on the invertebrate communities than the agricultural activities. Consequently, a study was conducted in the fall of 2000 to assess streams in the greater Vancouver area from 10 urban sites. In addition, repeat sampling was done at 3 sites in the Fraser Valley to assess year-to-year variation.

This bioassessment approach is continually evolving. As more reference sites are sampled and the range of habitat variables expands, the model will be rebuilt and refined. This study added only 15% more sites to the FRAP database and the GBEI model was similar to the FRAP model in terms of the predictor variables and the error rate. As more sites are added to the database, it is conceivable that the cloud of reference sites would become more dense as it is a continuum of benthic invertebrate assemblages. Therefore it would become more difficult to form well-defined clusters to which test sites would be predicted to and assessed with. The next step in the evolution of this approach may be to predict sites to a point in ordination space rather than to a defined faunal group. This is presently being examined by Dr. Trefor Reynoldson and Dr. Lee Grapentine at the Canada Centre for Inland Waters (Environment Canada, Burlington, Ontario).

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